ROCKY FLATS CLOSURE LEGACY

DECOMMISSIONING

DUE TO THE INHALATION HAZARD OF PLUTONIUM, MUCH OF THE D&D WORK WAS PERFORMED IN BUBBLE SUITS AS SEEN ABOVE. DUE TO THE INEFFICIENCIES OF DONNING AND DOFFING PERSONAL PROTECTIVE EQUIPMENT (TWO OR THREE TIMES A DAY), SOME PROJECTS WENT TO FOUR, TEN-HOUR WORKDAYS VERSUS FIVE, EIGHT-HOUR WORKDAYS.

DECOMMISSIONING

INTRODUCTION

"Decommissioning" scope can be defined as the safe removal of all facilities after the conclusion of operations, as distinguished from operations, where a "product" is produced, and environmental restoration involving environmental media (i.e. soil and water). Successful accomplishment of decommissioning scope was critical to the success of the Rocky Flats Closure Project because it represented most of the overall project scope and much of the project critical path. Despite a clear vision of what the overall decommissioned Site would look like – no buildings standing – the path to that vision was not at all clear; many interrelated decisions had to be made and sometimes remade before most tasks could even begin.

This section is divided into three subsections. The first discusses the progression of the decommissioning scope through the closure project, emphasizing the pilot projects and role of decommissioning in the overall closure project. The second subsection addresses the success factors for Site decommissioning, including the key closure project elements, and the impact of the learning curve, technology and other important factors leading to the Closure Project decommissioning success. A final subsection summarizes the key success factors for Site decommissioning.

DISCUSSION

Resumption of Production and Initiation of Deactivation

The Site recognized in the planning process that the plutonium facility decommissioning would be the bulk of the Closure Contract effort and key to overall Closure Project success. It implemented an organization to focus on executing that work.

Active weapons production operations at the Rocky Flats Plant were curtailed in December 1989, followed by a period during which the systems and infrastructure were developed to allow production operations to resume. During this "resumption" period, the Site identified numerous conditions that presented unacceptably high nuclear safety risks, such as the potential for nuclear criticality in liquid systems, container pressurization, and neglected building infrastructures. Once it became clear from the changing world situation that further Site weapons production was unnecessary and Site closure was inevitable, the Site initially focused on remedying these nuclear safety risks. With no more than a vague notion of the closure process or how wastes or plutonium would leave the Site, the task of reducing nuclear safety risk provided a goal, consistent with a Defense Board-mandate, and generally believed to be headed in the right direction for Site closure. The Site mission became "Deactivation," or a transitional state winding down operations and preparing for decommissioning and closure, as distinct from "Decommissioning," for which the regulatory path was still uncertain.

Initial Planning and Development of Decommissioning Scope

With the implementation of the Kaiser-Hill (K-H) Performance-Based Integrating Management Contract (PBIMC)[37] in 1995, greater emphasis was placed on Site closure and the role of decommissioning in that effort. One of the initial actions was the approval of the Rocky Flats Cleanup Agreement (RFCA)[3] in 1996, which established a regulatory framework between DOE, the State of Colorado, and the Environmental Protection Agency for decommissioning as a remedial action, and outlined the major requirements. Getting this overarching principle-based agreement in place was a critical first step, but significant effort and time was still required to establish the details of responsibilities, documents, and decommissioning regulatory process. Subcontractor organizations with the responsibility for decommissioning were formed, expertise was brought in, and some detailed planning began on some immediate, relatively low-risk projects and two significant pilot projects. Additional efforts that focused on establishing activities and logic for overall Site closure are discussed in Section 1.5, Creating and Implementing a Closure Project.

Contractor Organization and Infrastructure

A part of the overall Site planning effort was to determine how to prioritize activities and use the Site facilities and infrastructure. The Site was still organized around weapons or risk reduction operations functions, not closure functions. Identifying and shutting down functions and operations no longer needed for closure was not an easy task. Often an organization's overall justification would disappear, but imbedded functions that were previously a minor focus were still needed, such as limited calibration and metrology requirements remaining despite the elimination of the need for a weapons QA organization. Multiple reorganizations left parts of operations and staff scattered across the Site. This complicated the determination of facility status; i.e. whether a facility would be used in future operations, waste management, or other activities; and if not, should the facility be decommissioned now or "mothballed" for later demolition to reduce "landlord" costs. Ultimately K-H conducted a focused management initiative to address the splintered organizational functions. The effort was successful in streamlining the organization to closure, while maintaining essential support.

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Initial Decommissioning Projects

Several initial decommissioning projects emphasized small or high-visibility activities such as a small, obsolete, solid radioactive waste treatment facility; large unused fuel oil storage tanks; unused guard-posts;

and additional excess buildings. This served the purpose of showing visible changes to the Site and emphasizing its future closure, while not diverting substantial resources from the overall Site focus of nuclear risk reduction. Concurrently, planning was begun to deactivate and decommission two more difficult contaminated surplus facilities: Building 123, a 1950's vintage bioassay laboratory facility, and Building 779, the Plutonium Metallurgical Laboratory.

The purpose of these two projects was to pilot the Site "decommissioning process", i.e., the combination of regulatory, management, technical, authorization basis, work control, environmental, and contractual processes necessary to initiate, plan, execute, and close a decommissioning project. At the time the organizational responsibilities for different decommissioning functions (within the DOE, the contractor, and the regulators) were unclear, the regulatory process within RFCA had never been implemented, and there was very little organizational experience in doing decommissioning work. Early estimates showed that the Site decommissioning scope would increase from a few million, to hundreds of millions of dollars a year, a ramp-up level that would be nearly impossible to sustain. While gloveboxes had been removed from buildings several at a time, there had not been large scale removal of contaminated systems in preparation for building demolition – in fact, no plutonium-contaminated building had been demolished anywhere in the DOE complex under anything approaching the rigor imposed by current regulations. The Building 123 Project was completed in September 1998 and the Building 779 Project was completed in March 2000. The implementation of these pilot projects produced several notable results.

Pilot projects were necessary early on to develop and train staff; develop procedures, methods, and estimating parameters; and to develop working relationships and processes with regulators and stakeholders.

Resolution of Documentation and Regulatory Requirements

The Building 123 Decommissioning Project[89] was relatively straightforward from a technical standpoint. There was substantial asbestos and modest radiological and chemical contamination, but only low levels of transuranic (alpha) contamination. There were, however, over thirty significant documents covering regulatory requirements, authorization basis, work control, characterization, waste management, etc. that were often overlapping, sometimes conflicting, and all which had to be approved and in place before different aspects of work could start. As an example, there were three somewhat overlapping safety documents (the Facility Safety Analysis, the Auditable Safety Analysis, and the Health and Safety Plan), two somewhat overlapping waste documents (the Waste Management Plan and the Unit 40 RCRA Closeout Plan), and several characterization documents, all of which slightly overlapped with the regulatory decision document (the Proposed Action Memorandum). Part of this was the result of overlapping regulations (environmental regulation safety requirements vs. DOE Orders safety requirements), and part was a result of different organizations staking claim to a future role in decommissioning. The results of the lessons learned from this project were a more defined and streamlined approval process. Most importantly, the Site recognized the need to "keep approval of documents off the project critical path," i.e., decoupling the activity (with the implicit approval of regulatory agencies) from the physical work. Once the project baseline with related scheduling tools became more mature this became an even more powerful tool. The regulators never wanted a document approval to appear on the critical path for site closure.

Guard against the complexity of the work causing inaction. Minimize studies to determine the "best" approach. Develop a credible plan with best available information, proceed with work safely, and learn by doing.

Development of Size Reduction Techniques

The Building 779 Decommission Project contained over one hundred gloveboxes ranging in contamination from virtually clean to a few very highly contaminated gloveboxes (many grams of plutonium hydride). Several approaches were used to size reduce the gloveboxes, developing techniques in cutting metal, providing waste-acceptance-criteria-compliant packaging, and training operators and foremen in decommissioning equipment with progressively increasing levels of contamination. Methods for disposing of large volumes of debris waste were also developed using cargo containers and the Surface Contaminated Object (SCO) procedure[90] for waste characterization. While used only for potentially or moderately-contaminated equipment in the Building 779 project, further refinement of this approach provided substantial improvement in safety and efficiency, as discussed in detail later in the section.

Regulators accepted less up-front detail in the regulatory decision documents, in exchange for more active participation and commitments to better detail on future buildings as the planning process improved.

Development of Overall Processes and Infrastructure

The projects developed teams able to work together to resolve problems. This included work crews developing procedures and tooling, and project management teams developing estimating, project control, and conduct of operations approaches, etc. Finally, the pilot projects began the development of the oversight and regulatory interfaces, providing examples of what work control and other documents "looked like," so that the regulators, DOE, and the contractors could begin to work out roles and responsibilities in a practical environment. This also included the development of the Building Trades subcontractor staff, and interface approaches between subcontractors. These teams were transferred virtually intact to subsequent buildings, with some selected individuals "seeded" into other projects to assist in planning.

Learning Curve Benefit

The identification of these projects as "pilot projects" was useful in several ways. The projects were executed in an expedited fashion with substantial management attention, and showed considerable cost and schedule variance from the planned ideals. Overtime was used to maintain schedule as necessary. Decisions were made to use expedited documentation that resulted in less efficient execution, such as using an authorization basis approach that authorized individual activities instead of a blanket authorization for all building decommissioning activities. Regulators accepted less up-front detail in the regulatory decision documents, in exchange for more active participation and a Site commitment to provide greater detail on future buildings as the planning process improved.

As pilot projects, they were recognized to be at the beginning of the "learning curve" i.e., the concept that work becomes more efficient over time as workers gain experience, and that it was important to develop a baseline process that could be executed and then subsequently improved. If viewed as mature projects with good estimating bases and developed execution techniques, they were less than successful – they would be some of the more costly of the Site buildings to decommission on a per square foot basis. However, viewed in hindsight in the context of the overall Site closure, the learning curve benefits far outweighed the near-term inefficiencies.

In some buildings it was impossible to decontaminate some sections of concrete to meet the free release criteria and the concrete could not be removed prior to building demolition without damaging the structural integrity of the building.

Learning Curve Example – Release of Buildings

The evolution of the building decontamination process illustrates the iterative nature of the decommissioning learning curve. The original assumption was that radiologically contaminated buildings would be decontaminated to free-release criteria so that the buildings could be demolished and disposed of as sanitary waste. After all of the gloveboxes and equipment were removed from an area then the empty rooms were surveyed to determine the location and extent of contamination. Contaminated surfaces were then decontaminated using a number of techniques (described in more detail below). Additional surveys were performed to verify that the area was successfully decontaminated and that no cross-contamination had occurred, after which the facility could be released for unrestricted demolition in terms of radiological controls and waste disposal.

This approach was used successfully in Building 779; however, the decontamination process had to be adapted in subsequent buildings to address various contamination issues. In some buildings it was impossible to decontaminate some sections of concrete to meet the free release criteria and the concrete could not be removed prior to building demolition without damaging the structural integrity of the building. Instead these sections were decontaminated to the maximum extent practical, fixative was applied to prevent cross-contamination during removal, and the area was clearly marked with paint to allow the items to be segregated during demolition for disposal as low-level waste. In the most extreme cases, the contamination was so pervasive that it was impractical to decontaminate the building or area completely and attempting to identify and segregate small sections of "clean" rubble from contaminated rubble was inefficient and greatly increased worker risks. In these situations, the building or area was decontaminated to the maximum extent practical, fixative was applied, and hot spots were clearly marked. All of the remaining parts of the building that could be released was demolished and disposed of as clean waste. The targeted areas were disposed of as low-level waste as the building was demolished. The Site utilized large-volume rail shipping when entire buildings or large areas (such as canyons or heavily contaminated equipment foundations) were demolished as radiologically contaminated waste.

Repeated use of Hydrolasing actually caused residual contamination levels to increase, believed to result from the water pressure forcing contamination deeper into the concrete.

Hydrolasing[137] involved using high-pressure water to remove contamination from the surface of concrete walls, floors, and similar surfaces. The water also reduced airborne contamination levels during the process. A wastewater collection system was used to collect, filter, and re-use the water. This technique removed surface paint and a thin layer of concrete, allowing direct surveys for alpha contamination (i.e., unimpeded by paint) to detect any contamination that might be present in the underlying concrete. Hydrolasing, however, created its own unique set of issues. While useful for decontamination of fixed surface contamination, its repeated use (more than about 3 passes) caused residual contamination levels to actually increase, believed to result from the water pressure forcing contamination deeper into the more porous concrete substrate. Also, repeated hydrolasing passes caused such deep pockets and holes in the concrete that the use of large surface monitoring equipment for the final surveys to determine building pre-demolition status became almost impossible.

Mechanical Abrasion. When the contamination extended deeper into the material alternate methods such as scabbling and concrete shaving were used. The scabbling technique involved mechanical abrasion of the concrete surface with needle-guns or pneumatic hammers, breaking up the surface of the concrete. For horizontal surfaces, concrete-shaving devices physically removed the surface of the concrete. Scabbling and shaving removed more of the surface than hydrolasing and multiple passes could remove concrete layers more efficiently than hydrolasing. Both of these techniques used water for dust suppression and to reduce airborne contamination.

Concrete Section Removal. When the contamination was localized but extended deeply into an entire concrete wall or floor section then the entire section was often removed (as long as it was not load bearing). Workers used either concrete wet saw cut techniques for floors or a diamond wire saw cutting method for walls and ceilings to cut out those specific sections into pieces that were able to be handled by the work crew for disposal as radioactive waste. Another technique that was used to break up large blocks of reinforced concrete for disposal involved core boring into the concrete and injecting expansive grout. The grout would expand and crack the concrete allowing the large item to be broken into smaller sections for disposal (this technique was used on both contaminated and clean concrete).

Controls. Water sprays were used extensively during building demolition for dust suppression. Water jets and water sprays were used to suppress the dust generated during open-air demolition of all structures (contaminated and clean). If the structure was being demolished as a contaminated facility, then the water was collected by runoff channels surrounding the facility and diverted into collection pits which were then pumped into in a holding pond, handled as radioactive waste, and treated for reuse on the facility. All such water was recycled as long as demolition was going on at the site. After all building demolition was completed then the wastewater was treated and disposed of appropriately. During demolition within buildings many areas such as roofs and interior hollow cinder block walls were soaked with water prior to demolition to reduce dust generation and airborne contamination.

Sequencing of Decommissioning by Building

The Site contained four major plutonium operations buildings: Building 771, Building 776, Building 707, and Building 371, all of which were actively engaged in reducing the risks and consequences of nuclear accidents involving residual liquids, equipment, and stored wastes. Buildings 707 and 371 additionally were the locations of “operations” to stabilize plutonium residues, oxides, and metal prior to disposition off site. Since Site closure required disposition of these materials, these two buildings were not available for immediate decommissioning. Building 776, as the storage location for much of these materials, could begin decommissioning only after these materials were either processed or relocated. The non-plutonium buildings represented a lesser risk in their current conditions, could be more easily “mothballed,” and would have shorter overall project durations that would avoid their impacting the Site critical path; hence they became lower priority. Thus, although there were some smaller activities to continue risk reduction (e.g. removing enriched uranium from Building 886), the post-pilot decommissioning efforts focused on Building 771. Building 776 was anticipated to follow once its accountable material had been relocated.

Deactivation/Decommissioning Interface

Building 771 had contained the bulk of the Site's high-concentration plutonium solutions at the curtailment of weapons production, and a substantial portion of the building's subsequent nuclear risk reduction activities had been draining tanks and solidifying the plutonium-containing liquids. This provided an operating cadre available for subsequent "deactivation" activities. As the draining of the tanks was completing and efforts were turning towards the residual liquids in the piping systems, a decision was made to remove not just the liquid but the entire run of piping. This was labeled as "deactivation," and not "decommissioning," since "decommissioning" would have been a "remediation" activity covered under RFCA. Based on this decision there was no regulatory coverage for "remediation (the Decommissioning Program Plan[26] and the Building 771 Decommissioning Operations Plan (DOP)[91] were not approved) and the EPA and the State regulators were kept at a distance. Labeling the work deactivation also identified it as a "nuclear operation" and therefore within the scope of the PBIMC "nuclear" subcontractor and not the PBIMC "remediation and waste" subcontractor. Waste was managed under the provisions of the Resource Conservation and Recovery Act. Piping was removed as a means of advancing the closure process as well as preemptive action against risks from further system degradation.

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In retrospect, since decommissioning was the building endpoint, the attempt to do closure work as deactivation was of limited benefit. The removals engendered arguments and mistrust with the regulators, who viewed it as circumventing RFCA. The distinction between deactivation and decommissioning caused work to be organized and executed less efficiently than if all work had been covered under RFCA and included in area-specific Sets (see below). Once the Building 771 decision document (i.e., the DOP) was approved, all of the subsequent deactivation work was performed under the RFCA (i.e., CERCLA) framework, and all waste was managed as remediation waste. The action to segregate deactivation for regulatory and management purposes was seen as a poor decision and not repeated.

Detailed Decommissioning Planning/Use of "Sets"

Concurrently with the Building 771 Deactivation, planning and estimating for the decommissioning of the plutonium process equipment was proceeding, including the removal and size reduction of process gloveboxes, tanks, piping, and duct. This planning incorporated the methods and the cost estimating factors from the experience being gained in the (at that time) early stages of the Building 779 project. Building 771 was the first building to focus on planning the process equipment dismantlement based on "Sets" – groupings of equipment typically in the same room or portion of a room that would be worked as a unit – and defined in the Building 771 DOP. The Sets were area-based, as opposed to the deactivation activities, which removed runs of process piping that crossed several areas, making the planning and execution easier. The Sets were planned based on the methods used in Building 779, with early identification of problems for which there was no acceptable current approach to allow investigation of different technologies. Sets were initially prioritized and scheduled based on numerous criteria. These included initially performing easier work sets both to create space for logistics and waste, to allow newly forming work crews to succeed, remove gloveboxes so that support ventilation system could be removed, and clear out areas of highly-contaminated equipment so that the less experienced Building Trades subcontractors could accelerate their work. Although the sequencing changed as the Building 771 project progressed, the Set concept was robust enough to avoid substantial replanning of the Set content, and provided the basis for project tracking and control.

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Decommissioning Program Development

In 1998 a separate K-H decommissioning program function was established to begin coordinating and refining the processes and infrastructure for the expanding decommissioning effort which had previously been the scope of the PBIMC execution subcontractors. This program evaluated the efforts to plan, estimate, and execute the Building 123 and Building 779 pilot projects. This resulted in cost modeling that would support the subsequent baselining effort, documented in the Facilities Disposition Cost Model.[196] The facilities disposition process was flowcharted and the documentation and approval process established in an attempt to resolve conflicting document requirements, streamline the planning effort, and allow decommissioning to be discussed in common terms. This process development resulted in the Facilities Disposition Program Manual.[92] The effort to create the decommissioning RFCA Standard Operating Protocols[30,31,32] was initiated to standardize and streamline the regulatory process. Site-wide facilities characterization methods and procedures were developed, and documented in the D&D

An initial problem was too many interdependent decisions, priorities, and schedules that made it difficult to develop a baseline. Use outside experience, coupled with Site knowledge, to analyze and resolve project challenges.

Characterization Protocol.[27] Cost modeling, additional activities to streamline the regulatory process, development of a characterization process, Site waste estimating, and planning and estimating for the decommissioning of the remaining Site facilities were begun. An ill-fated effort was initiated to develop a robotic size reduction facility that could support the remaining plutonium building decommissioning, and is discussed in a later section. Overall, the Program provided substantial support to the subsequent Closure Project Baseline[39] development and created a number of Site-wide documents that were used throughout Site closure. As the Site reorganized following the initiation of the Closure Contract, the Program functions were distributed among the resulting Projects.

Development of the Closure Project Baseline

In 2000, DOE awarded K-H a contract to complete the Rocky Flats Closure Project.[33] As part of the reorganization and rebaselining effort decommissioning efforts were divided into five distinct execution projects – the four major plutonium processing buildings and "everything else", which included one smaller plutonium laboratory, five uranium and beryllium processing facilities, and several hundred non-contaminated or lightly-contaminated structures. A sixth execution project was responsible for waste management and security. Various separate K-H site-wide organizations were responsible for planning, business processes, safety and regulatory oversight, etc. Functions necessary for successful project execution, such as procurement, engineering, and safety were projectized; i.e., each execution project had independent procurement, engineering, and safety organizations reporting to the execution project manager. The residual Site functional organizations coordinated Site policy and supported Site-level (but not project-level) execution. The execution projects were given a five-month period to complete a detailed baseline schedule and estimate through the completion of building demolition, with overall cost and schedule parameters based on the Site master schedule. This process is described in more detail in the section on Creating and Implementing a Closure Project, and the elements particularly relevant to decommissioning are discussed below.

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Status of the Closure Project Baseline Execution

Since the initiation of the Closure Project activities in July 2000, decommissioning execution proceeded essentially consistent with the planning incorporated in the Closure Project Baseline. The overall Closure Project had favorable cost and schedule variances since 2002, largely as a result of some schedule acceleration of outyear activities. Improvements in glovebox size reduction resulted in some critical path schedule improvement. This was somewhat offset by delays in shipment of accountable nuclear materials from the Site, and the potential impact on final closure of the Protected Area and removal of much of the remaining nuclear and security infrastructure. There was some reorganization to combine the management of the execution projects for improved efficiency, although having separate projects encouraged the development of slightly different approaches toward resolution of similar problems. The Site re-evaluated the extensive use of fixed-price contracting for the less-contaminated Building Trades work, based on difficulties in new contractors moving up the learning curve for doing work on Site. All tasks had acceptable methods identified and in most cases implemented. Although there was some rearrangement of activities within the individual Projects, the overall baseline structure and estimate was relatively resilient.

DECOMMISSIONING FEATURES

The following section discusses the elements that supported the Rocky Flats Closure Project success in decommissioning facilities.

Closure Project Organization

The actions taken following the approval of the Closure Contract had a profound positive effect on Site closure. The Closure Contract and subsequent rebaselining effort provided a number of key elements:

A credible baseline through the completion of the Closure Project. Previous to the rebaselining there were parts of the Closure Project that were well planned, typically near-term activities similar to ongoing work. There were also numerous unplanned parts, typically out-year work for which no organization had clear responsibility. Examples included building demolition, decommissioning of uranium-contaminated facilities, and decommissioning of large, highly-contaminated vaults. The 2000 Closure Project Baseline supported accurate planning, assessment of progress, and reporting. Emphasis on additional schedule acceleration through shortening the critical path and on planning of the end of the Closure Project would have been impossible without the level of rigor provided by the baseline. Demolition and environmental restoration activities within the building footprint were integrated through the schedule, so changes in Project schedule would be reflected in restoration planning, as appropriate. Although the Baseline provided a detailed basis for management, a more detailed level of planning (i.e. the work control documents) was conducted using the "rolling wave" approach of having work packages prepared just a few months before they were needed. This

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turned out to be a very successful work planning model, allowing the detailed work packages to be prepared under a "just in time" concept, and thus take advantage of the latest in technical, regulatory, and management lesson learned.

Clear scope and responsibilities, and authority vested with Project Manager to focus on and execute their scope. Under the Closure Project, all decommissioning scope became building-based with no functional management; e.g., no "D&D Program." All Projects (e.g. the 771 Project) had distinct cost and schedule baselines over which the vice-president level Project Manager had complete funding and decisionmaking authority. Functions necessary for successful project execution, such as project control, procurement, engineering, and safety were assigned to the Project, and staff in those functions were paid for and reported to the Project Manager. Although there were some residual Sitewide organizations, they were typically not in the decisionmaking chain, and generally provided support at the Project Manager's discretion. This accountability also provided an unambiguous means of identifying project personnel value and improved the ability to control costs and staffing. Cooperation and coordination between Project Managers was accomplished by leadership from the most senior contractor management and Corporate Board, rather than through an organizational structure. The contractor's most senior managers successfully managed this delicate balance between building and Site priorities, but only with continuous engagement.

Relocation of plutonium stabilization operations to Building 371. The Security Reconfiguration effort centralized all "operations" previously spread throughout the plutonium buildings into a single building, so that all such non-decommissioning plutonium activities were removed from the other three Plutonium buildings. In addition to the dramatic reduction in costs to support security compliance, the ability of the three facilities to focus on decommissioning increased, and the change in the culture resulted in improved decommissioning performance. Similar distinct divisions between operating and decommissioning were established for the non-plutonium facilities, such that buildings that had a continued waste management mission remained distinct from those either awaiting or undergoing decommissioning.

The division of the [Steelworker and Building Trades] scope during the planning process was necessary to allow contracting and proper scheduling of activities.

Division of the decommissioning scope between process systems and utilities/structural decontamination/demolition. This was an issue of distinguishing between the work that would be done by Site bargaining unit craft labor (United Steelworkers of America) and the work that would be done by construction crafts (Building Trades). There was early recognition that a construction workforce greater than that available within the current Site Steelworker ranks would be required to achieve accelerated closure. The division of the scope during the planning process was necessary to allow contracting and proper scheduling of activities.

The divisions of scope included separating the work in a given room or rooms between those removals that were highly contaminated from those that were less contaminated. Note that all of this work was considered decommissioning, not deactivation. The Site Steelworkers first removed the equipment included in their work scope. They then moved to other areas and the Building Trades removed the remaining equipment, utilities, non-load bearing walls, decontaminated structural surfaces, and (eventually) demolished the buildings. Anticipating and separating this work within the Closure Project Baseline allowed the work to be appropriately contracted, scheduled, and controlled, and would have been much more difficult after work had started.

Significant advance work was necessary to allow this separation and coordination in the work planning. Steelworkers and Building Trades do not naturally cooperate, and in fact jurisdictional issues between the two labor entities resulted in a labor strike during construction of Building 371 in the 1970's. Resolution of that strike resulted in a complex labor agreement defining strict jurisdictional boundaries. K-H had to approach both the Steelworkers and Building Trades to develop cooperative approaches that would be seen as benefiting the members of both groups. Their success in this effort enabled the efficient division of work during the decommissioning.

The Learning Curve

The decommissioning process at Rocky Flats can be described as surprising; surprisingly confused and inefficient at the beginning, and surprising improvement within a relatively short time. A "learning curve" effect is traditionally thought of as the result of improvement in workforce experience, which was certainly part of the process as the workers, most often former process operators, become more comfortable as D&D workers. During the initial decommissioning Sets the efficiency was low; as the understanding of the work improved, the tooling became more sophisticated, and techniques for contamination control became better. The crews also began acting more as teams, anticipating each other's actions in removing personal protective equipment, for example. K-H placed substantial emphasis on empowering its first line supervision (foremen) and in improving both training and management oversight, which resulted in improvements in crew efficiency. There was also a reduction in injuries and accident statistics, which had a collateral efficiency improvement from reduced shutdowns.

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An additional area of improvement was in work planning and procedures. Much of the early inefficiency was due to downtime caused by inadequate or incorrect work documentation. Through feedback and increased experience by the engineering and planning staff on decommissioning work, the packages became more timely and accurate, resulting in less work stoppage. Additional efficiency came from improvement in the methods of work and identifying and eliminating barriers and unnecessary activities. Examples of improved methods included the decreased reliance on size reduction resulting from improved glovebox decontamination and use of vacuum cleaners to remove raschig rings; use of plasma arc required significant efforts to overcome safety concerns. Submitting detailed facility characterization plans to allow the release of office trailers awaiting regulator approval was eliminated through increased involvement by the regulators in planning and implementation oversight. Another was consolidating facilities in a way that allowed one document to cover multiple facilities, minimizing the administrative and regulatory effort.

Impact of Pilot Projects

Two elements in particular were important in moving rapidly up the learning curve. The first was early initiation of larger-scale pilot projects discussed earlier, which allowed problems to be resolved on one project instead of having to be addressed by all projects simultaneously. Thus the inevitable delays and cost variances were not repeated, nor was the Site closure end date impacted. The other Projects all moved up the learning curve by incorporating the piloted approaches in their planning and baselines. Additionally, it allowed for development of crews, staff, and management teams, and replacement of under-performers.

The learning curve for dismantlement, decontamination, and demolition of uranium and beryllium contaminated facilities was greater than anticipated, even for firms with experience with contaminated decommissioning elsewhere

Learning Curve Impacts for Subcontracted Work

The above discussion looks at the Site improvement in performance as a result of learning curve efficiencies, with the result that the Site management and workforce developed a certain level of expectations for performance and safety. However, learning curve issues also caused a rethinking of the use of fixed-price contracting for lesser-contaminated facility decommissioning. Despite attempts to make the demolition of clean facilities similar to commercial construction, there remained Site-specific requirements and expectations for safety and conduct, and personnel interactions that needed to be achieved to accomplish work. The learning curve for dismantlement, decontamination, and demolition of uranium and beryllium contaminated facilities was greater than anticipated, even for firms with experience with contaminated decommissioning elsewhere, as shutdowns in Building 865 demonstrated.

The fixed-price subcontractor performing the dismantlement, decontamination, and demolition of a plutonium facility from which the process equipment was removed had also taken substantial time to achieve adequate productivity. The Site evaluated different methods of self-performing Building Trades work, use of cost-plus contracts, and Site Steelworkers being hired as Building Trades craftsmen to mitigate this problem.

Beryllium and Asbestos Contamination

Although the radioactive contaminants typically receive most of the attention for decommissioning, beryllium and asbestos provided significant challenges in the overall decommissioning effort. Asbestos was found in far more places than originally anticipated. Asbestos was unexpectedly ubiquitous in interior and exterior wallboard, spackling and grouting material, and floor coverings. For worker safety, asbestos-containing materials (ACM) were removed prior to demolition activities, (but generally after facility radiological decontamination) and segregated for waste disposal. The extensive ACM removal provided substantial work sequencing and control challenges, and unexpectedly appeared on the critical path for demolition of several major facilities. In the case of Building 776/777, the exterior wall panels were all determined to be ACM. An elaborate subproject replaced the complete "skin" of the building, removing ACM panels one at a time, and replacing them with a temporary non-ACM panel, so that the negative differential pressure could be maintained within the building. One positive aspect of the ACM challenge was the success of the ACM removal subcontractors. The Site focused on niche subcontractors with expertise in ACM removal. These were some of the best performing subcontractors, working safely and effectively, even considering the hazards of the asbestos.

The extensive ACM removal provided substantial work sequencing and control challenges, and unexpectedly appeared on the critical path for demolition of several major facilities....The lesson for other sites is to plan for more asbestos and beryllium contamination than would be expected based on historical knowledge or even initial sampling.

Beryllium (Be) contamination also provided unique challenges. Originally the Site anticipated that only a handful of non-nuclear production facilities would be Be-contaminated. As facilities were characterized the Site found Be contamination in nuclear facilities and even some administrative support areas. There is still no device that can provide real-time detection of Be contamination. Smear and swipe samples, lapel samplers, and other air samples collected in the field must then be analyzed in a laboratory usually with no less than a 24-hour turnaround. For their protection, workers in areas with suspected Be contamination were required to wear respiratory protection until it could be proven that Be was not present. Even this was not completely successful. Several instances occurred where a room was surveyed and found to be free of Be contamination only to have Be uncovered during the removal of a large piece of equipment. Further complicating the work planning and resource scheduling was the DOE's desire to limit the number of Be workers, since any Be worker became part of the Chronic Beryllium Disease Prevention Program, with a lifetime commitment for health screening and potential to develop Chronic Beryllium Disease. With additional training and management attention the Site worked through both the Be and ACM challenges. The lesson for other sites is to plan for more asbestos and beryllium contamination than would be expected based on historical knowledge or even initial sampling.

Influence of Technology

The decommissioning activities at the Site demonstrated the capabilities and limitations of applying technology to decommissioning problems. Several problems were resolved by the focused use of technology applied to a specific problem. The technical improvement with the biggest single impact was the ability to decontaminate plutonium process equipment such as gloveboxes and tanks from a transuranic waste form to a low-level waste, and in the process substantially reduce or eliminate the size reduction effort. This was accomplished by a combination of localized decontamination using either cerium nitrate or the EAI 3-step process, and waste characterization using "surface contaminated object" procedures as described below.

The technical improvement with the biggest single impact was the ability to decontaminate plutonium process equipment such as gloveboxes and tanks from a transuranic waste form to a low-level waste, and in the process substantially reduce or eliminate the size reduction effort.

Building 779 Size Reduction Requirements

During the Building 779 project, the only accepted way to determine plutonium levels for characterization of process equipment-generated wastes was to use non-destructive assay machinery, which could not accurately assay larger containers. Therefore, all plutonium process equipment was sprayed with fixatives to minimize plutonium airborne activity, and then manually size reduced to a size that could fit in a "Standard Waste Box," the largest container available for disposal of transuranic waste. Manual size reduction of plutonium process equipment was very labor-intensive, with several support personnel outside of a contamination control structure supporting each supplied-air plastic-suited worker using manual cutting tools inside the structure. The potential for personnel contamination and cutting injuries was high.

Conversely, non-process equipment-generated wastes, such as debris from room-air ducting and desks from process areas, could be placed into much larger cargo containers for disposal as low-level wastes at the DOE Nevada Test Site facility. The wastes could be radiologically characterized using the DOT SCO procedure. This is a straightforward process that used direct readings and smears from all surfaces of an object to determine average levels of surface contamination to give a total activity for the object. For materials at lower contamination levels it could be done with existing instrumentation. Initial evaluation showed that some, mostly laboratory, gloveboxes could be decontaminated and then characterized using existing decontamination techniques and the SCO procedure. The remaining gloveboxes would both exceed the measurement capabilities of existing equipment and could not be adequately decontaminated using existing techniques. Thus, it appeared that the majority of the Site's gloveboxes would require manual (or perhaps automated) size reduction.

Decontamination Technology Development

Three technology development efforts were pursued. First, instrumentation was developed to accurately determine contamination levels in the range of 10-100 million disintegrations per minute-alpha. Simultaneously, two approaches were evaluated for in-glovebox decontamination. One involved the adaptation of a process to dissolve plutonium oxide using cerium nitrate that had been used for tank decontamination. A second brought in a subcontractor (EAI) for application of proprietary chemicals in a multi-stage process. These methods successfully reduced the number of gloveboxes requiring manual size reduction by about 80% and resulting in a similar reduction in transuranic waste for a substantial savings in waste management costs. The decreased reliance on manual size reduction and acceleration of Closure Project schedule resulted in hundreds of millions of dollars of cost savings over the Closure Project.[94]

Problems with Robotic Size Reduction

A technology development effort that proved less successful was a project to implement a robotic size reduction facility. This facility was designed and procured based on programmatic studies of anticipated needs, not at the request of any Project (in fact before the Projects actually were organized). After spending approximately seven million dollars in development and procurement costs, the installation of this facility was halted. This was principally due to the success of the decontamination/SCO methods for glovebox dismantlement, continued improvement in manual size reduction facilities such as the use of plasma arc cutting, and improved work skills that resulted in better contamination control. Additionally, there were concerns that benefits of the robotic system, less worker exposure and faster size reduction for standard parts, would not compensate for substantial startup and debugging time and costs and the reduced flexibility for non-routine activities. Problems already being experienced with the automated Plutonium Stabilization Packaging System also influenced the decision.

Technology development was most successful when the Project initiated it to solve one of their problems and with Project buy-in and cost sharing.

Technology Development Approach

There were several factors that the Site considered when it evaluated how to approach technology development:

- Technology development was most successful when the Project initiated it to solve one of their problems and with Project buy-in and cost sharing. It was least successful during accelerated closure when initiated by a technology development organization (a solution looking for a problem).

- Evaluation of technology options must involve active participation of workers at the foreman level or below – even if a technology works, if there is no buy in from the workers, then it will not be used effectively.

- Incremental improvement, mostly with off the shelf items, yielded large benefits in increased productivity. Often one good idea leads to another – if management is open to the continual, incremental improvement.

- Employing contractors with specific expertise, such as for characterization or decontamination (perhaps with a contractual capability to transition to Site staff at some later date) is preferable to developing technology in-house.

During planning a number of “intractable” problems – activities for which there was no clear approach – were identified, such as clean-up of vaults with extremely high levels of airborne contamination. Technology development was initiated to investigate several technologies at once, using DOE Office of Technology Development funding support. The development timelines were evaluated to ensure that the candidate technologies would be available in time to be used – fortunately no completely undeveloped technology was needed.

Technology Development Practical Applications

Specific technology development activities are briefly described below and in more detail under Section 12, Technology Development. The Technology Development section contains references additional documents providing more detailed descriptions of the topics.

Plasma Arc metal cutting – Plasma arc torches were used to cut sheet metal in size reduction. Depending on the material to be cut (metal thickness, contamination level), sometimes the costs of the additional safety requirements and contamination cleanup were not worth the increase in cutting speed. Also, the plasma arc traded reduction in worker skin contamination and repetitive motion injury risks, for increased fire and contamination spread risks. Considerable effort was required to develop an adequate authorization basis to allow the system to operate. Plasma arc was used effectively to cut up massive in-glovebox equipment after addressing safety concerns.

Fogging – Fogging uses an aqueous solution of soluble materials (e.g., glycerol) that is turned into an aerosol and introduced into a stagnant contaminated room or other compartment. The aerosol absorbs and suppresses any airborne contamination, and adheres to all surfaces, mildly fixing contamination even in less exposed areas (e.g., electric motor windings). This technique is extremely useful in reducing "derived air concentration" levels and contamination spread in highly contaminated environments, although fogged contamination may adhere to clothing or booties, potentially spreading (but not significantly re-suspending) contamination. Placing a dye that is visible in ultraviolet in the fog allows support personnel to easily locate places on a worker's protective clothing that have brushed against fogging materials and may be substantially contaminated.

The challenge of waste estimating is recognizing when waste estimating assumptions change and adjusting the waste estimates when the project makes a decision affecting them…The more important lesson is to view waste generation and resulting disposal costs within the total project context.

Strippable coatings and fixatives – These coatings are designed to fix contamination in place. Alternatively, certain latex-based coatings can be applied by spray, brush, or roller and, when dry, pulled off the surface to remove surface contamination in a stable, disposable form. The fixatives may be flame retardant to allow safe use of plasma arc cutting. Coatings may be used over fogged surfaces to decontaminate or permanently fix contamination.

Waste estimate tracking – Methods were developed to estimate waste generated during decommissioning activities based on early decommissioning pilot projects. The pilot projects were used to extrapolate waste generation for subsequent building demolition. The initial estimating technique was not very accurate. Although there were some improvements in waste estimation, the estimating process was complicated by the fact that the Site identified methods to decontaminate and dispose of significant quantities of low level waste (LLW) that were originally assumed to require disposal as transuranic waste. Additionally the volume of LLW increased tremendously when the decision was made to demolish several buildings/areas as LLW instead of the original assumption that the buildings would all be decontaminated to allow demolition and disposal as sanitary waste. In cases where the Site chose an alternative decommissioning method that generated more waste, the cost savings in decommissioning worker efficiency usually offset the additional waste cost; i.e., the overall project cost was reduced. The method also expedited critical path activities allowing closure acceleration. While not a decommissioning issue, the ER program underestimated the amount of contaminated soil that would require disposal, contributing to the quantity of LLW that required disposal in excess of that estimated. The Site's sanitary waste volumes dramatically exceeded the planning estimates.

The challenge of waste estimating is recognizing when waste estimating assumptions change and adjusting the waste estimates when the project makes a decision affecting them. At Rocky Flats, for several years these decisions to address decontamination issues or increase project efficiency were occurring at a rate and frequency that made it almost impossible for the planners to accurately estimate waste volumes; instead they were usually bounded (even then the assumptions sometimes proved wrong). Ultimately, the waste programs recognized that waste estimates were just that: "estimates" and that the Site would continue to generate and characterize waste until the Closure Project was complete. Only then would a final volume be known. Although the Rocky Flats waste estimation experience may help other sites in their waste estimating process, the variability of waste generation processes at each site limits the applicability of the Rocky Flats experience. The more important lesson is to view waste generation and resulting disposal costs within the total project context.

Property disposition per the DOE Orders, not CERCLA – A decision process was developed to support facility disposition for small facilities. In these cases, it was feasible to treat a facility (e.g., a small trailer) as property and release it for offsite reuse or sanitary disposal. This can avoid excessive characterization costs under CERCLA.

The disposition of uncontaminated real and (government-owned) personal property in compliance with CERCLA and DOE regulations can require an effort out-of-proportion to its nominal risk or overall project importance.

Disposition of personal property – The disposition of uncontaminated real and (government-owned) personal property in compliance with CERCLA and DOE regulations can require an effort out-of-proportion to its nominal risk or overall project importance. A decision process was developed to streamline the government process to dispose of real property.[95,96,200,201] It included an initial inventory that identified and verified the location and contamination status of all Site personal property. Negotiations on property disposition requirements were held with the General Services Administration. As a result, the valuation of contaminated property took into account the cost required to decontaminate it. In practice, the value of most property resulted in a net of no value – it was waste and could be taken off the books. Finally, a congressionally authorized "pilot project" allowed the revenue from the sale of government-owned personal property at Rocky Flats to be applied to cleanup effort. An aggressive program of matching high-value (typically weapons-mission) equipment with the needs of other DOE sites provided additional value to the department.

InstaCote for packaging of large equipment – A method was developed to place large pieces of contaminated equipment on metal pallets, fix and shrink-wrap the equipment, and then use a multi-coat durable spray coating to serve as a "strong, tight container" for disposition of low level waste.

Raschig Ring removal – A critically safe vacuum cleaner system was developed to allow removal of raschig rings used for criticality prevention from tanks, avoiding handling of highly contaminated glass shards.

Chipless Duct cutting – Tooling was developed to cut round process system duct using rotating blade system similar to a tube cutter. This resulted in substantially easier duct removal with reduced contamination spread.

Facility Characterization improvement – Procedures and analysis techniques were developed to conduct MARSSIM-compliant facility surveys to allow unconditional release of facilities. The processes include streamlined paperwork and sample plan development, data collection that downloads survey data directly to databases, and automatic scanning equipment for areas that require 100% scanning.

Explosive Demolition and Equipment Dismantlement – Controlled explosive charges have been used both to knock down buildings and also to create "harmonic delamination," cracking structures and substantially increasing the efficiency of conventional construction equipment in building demolition. Controlled explosives have also been used to dismantle equipment (e.g. drop ducts suspended near ceilings to the floor to avoid extended elevated work). All explosives use was in non-contaminated environments. Substantial effort was exerted to achieve public acceptance, and widespread application was limited by the additional safety and planning steps necessary to use explosives for whole building demolition.

Personnel Incentives

There was an early recognition that most of the Closure Project critical activities involved process system equipment removal, and that this would be done by Site bargaining unit staff (i.e., the Site Steelworkers) that would be retrained for that purpose. Real concern existed about the willingness of individuals to change from operators to D&D workers and to accelerate work that would result in more rapidly putting them out of a job.

The issue was addressed in a global fashion by trying to align the interests of the workers with that of K-H and the DOE… liberal use of overtime, improving the effective rate of pay for the Steelworkers… Several methods were used to provide increased compensation for D&D worker supervision, who were made directly accountable for the decommissioning activity schedule.

The issue was addressed in a global fashion by trying to align the interests of the workers with that of K-H and the DOE. This was done in three ways. First, the contract was renegotiated to delineate between Steelworker and Building Trades crafts based on level of contamination (e.g., 2,000 dpm-alpha) instead of the normal Davis-Bacon divisions. This allowed the workers best trained for higher radiological work and those best trained for construction equipment to be appropriately placed, and also ensured that the Steelworkers would move from building to building as the Closure Project progressed, ensuring their jobs as long as higher radiological hazards work remained. Second was the liberal use of overtime, improving the effective rate of pay for the Steelworkers. Third, the Steelworkers received an annual incentive bonus based on schedule performance, and there were considerable spot bonuses provided at completion of specific activities, ranging from items such as dinners to cash awards of several hundred dollars, given often. In addition to the Steelworker staff, it was recognized that the D&D worker supervision was critical to achieving the required acceleration. Several methods were used to provide increased compensation for these staff that would be directly accountable for decommissioning activity schedule.

Although not exactly a personnel incentive, the Site supported personnel outplacement as work in certain job categories decreased. In the case of the Steelworkers this included assistance in moving into Building Trades unions to do Rocky Flats decommissioning work as Steelworker work was diminishing. This program involved in excess of 150 Steelworkers and provided as much as a year of additional employment; many former Steelworkers continue to perform Building Trades craft work at other locations throughout the Denver area.

Other Factors

One consistent theme for the decommissioning Projects, as well as the Site as a whole, was the need to change the culture. While this is discussed in other sections, within the context of decommissioning it is the emphasis on the construction aspects of the work. A number of actions were taken to promote this culture change. In one case Project personnel were moved out of in-building offices into construction trailers. Part of the reason was to free up in-building space for logistics, but more important was to drive home the point that operations were over.

One consistent theme for the decommissioning Projects, as well as the Site as a whole, was the need to change the culture… Consistent with changing the culture was bringing in off-site expertise and attitudes.

Consistent with changing the culture was bringing in off-site expertise and attitudes. This involved the insertion of senior managers with outside experience at the execution project level while retaining substantial Site staff. Staff level personnel with outside expertise were also inserted. This encouraged the introduction of different approaches while taking into account unique Site considerations. Although it took time to achieve a cohesive team, having a single composite Project organization minimized the difficulties of organizational interfaces such as would occur if a number of contractor organizations were used.

The demand for small tooling for the decommissioning execution was much greater than anticipated. Examples are sawsalls, nibblers, lift tables, and engine hoists. Opening up the "supply chain" substantially reduced down time caused by a crew waiting for the right tool. Tool selection was typically a crew decision. Putting in place the procurement and tool inventory was a simple step that became a significant contributor to Project success. In one special case a needed replacement part was flown on a dedicated aircraft from halfway around the world. Although the cost was over $50,000 for what normally would have been a $100 delivery charge, delay time for normal delivery would have exceed several million dollars. This holistic view of the Project and work crew needs was repeated in less dramatic fashion on dozens of occasions, and extended to selection of personal protective equipment and other "simple" worker preference items. Getting the right tools to the workers in as quick and easy a manner as possible became part of the basic support approach that increased the efficiency and morale of the workforce.

KEY SUCCESS FACTORS

1. The Site recognized in the planning process that the plutonium facility decommissioning would be the bulk of the post-Closure Contract effort and key to overall Closure Project success. It implemented an organization to focus on executing that work.

2. Pilot projects are necessary early on to develop and train staff and facilitate development of procedures, methods, and estimating parameters, and development of working relationships and processes with regulators and stakeholders.

3. Guard against the complexity of the work causing inaction. Minimize studies to determine the "best" approach. Develop a credible plan with best available information, proceed with work safely, and learn by doing, with a bias toward continuous improvement.

4. Weed out competing priorities that are not mission-oriented.

5. Glovebox decontamination is useful because it reduces cost and increases safety due to less cutting. Other benefits, such as less cost to

manage LLW vs. TRU, are collateral benefits, not the principal drivers. Several different approaches were used to get to the goal; the ability to achieve LLW classification is dependent on historical glovebox service.

6. Manual size reduction of plutonium-contaminated equipment is dirty work with significant occupational safety risk. Its redeeming virtue is that people are very flexible in handling different material configurations (as opposed to robotic or automated processes).

7. Decisions to use in-house staff vs. fixed price contracting depend on how similar the work is to routine construction, (including Site-specific requirements like a "beryllium program") and whether traditional construction accident rates are acceptable. As the work becomes less standard, disadvantages like supplemental training, commercial vs. Site safety practices and learning curve inefficiency may outweigh the cost benefit of competitive procurement.

8. Organize for success – projectize based on facilities or areas, not functions, to encourage management focus on closure.

9. Integrate project staff with outside decommissioning expertise and personnel with knowledge of Site processes and infrastructure.

10. An initial problem was too many interdependent decisions, priorities, and schedules that made it difficult to develop a baseline. It just takes hard work and time to get though it. Use outside experience, coupled with Site knowledge, as a template whenever possible.

11. Work the evolution – encourage incremental improvements in efficiency to yield large collective efficiency improvement.

12. Identify "intractable" problems early and begin working multiple paths toward solutions – in some cases the paths may combine.

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